LEACHATES FROM DECOMPOSING LEAVES

I. SOME GENERAL CHARACTERISTICS[1]

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Processes of soil formation are characterized by transportation and deposition of materials, both organic and inorganic, within the soil profile. The visible evidence of such movements is particularly apparent in the profiles of podsol and of certain podsolic soils, the striking colour spectra of which are due, primarily, to localization of accumulation of organic materials and of compounds of iron. The mechanisms involved in the translocation and localization processes which result in the observable profile variations in such characteristics as colour, degree of cementation, and concentration of iron compounds remain obscure. It seems probable, however, that, in the case of podsol soils formed under forest vegetation, substances leaching from the organic layer overlying the soil play an important role in the development of the characteristics distinguishing the profiles of such soils. Investigations, the objectives of which are to obtain information on the rate of decomposition of litter reaching the forest floor and on the characteristics of leachates produced from the litter by natural precipitation were begun in 1947. In a previous paper (1) data on the annual leaf-fall of some deciduous forest trees, on the composition of leaves collected as they fell, the composition of such leaves after partial decomposition, and on the properties of leachates collected from the leaves during decomposition, were presented. The purpose of the present communication is to provide further data respecting the nature of these leachates.

EXPERIMENTAL MATERIALS AND METHODS

The procedure followed in gathering the leaves, and the apparatus and technique employed in the collection of leachates, have been described previously (1). The experimental arrangements for leaf exposure and leachate collection are illustrated in Figures 1 and 2.

Leaves of sugar maple were obtained from trees growing on Grenville (St. Bernard) soil, those of American beech and of poplar from Rubicon (St. Amable) soil, and those of gray birch from a soil of the Courval series in 1947; thereafter from Uplands sand. These soils have been described by Lajoie and Stobbe (2). They are classified as belonging to the following great soil groups; Grenville, brown forest; Rubicon, ground-water podsol; Courval, gray hydromorphic (dark gray gleisolic); Uplands, podsol.

The periods when collected and the conditions of exposure of the leaves are indicated in Table 1.

In the summers of 1950 and 1951 the decomposing leaves were inoculated with soil suspensions. This was done in an attempt to ensure the presence of a normal microbial flora. The inoculum was prepared as follows: Samples of soil to a depth of 2-3 inches were taken in or near the

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TABLE 1.—COLLECTION PERIODS, TREATMENTS AND DURATION OF EXPOSURE OF LEAVES

Leaf collection period	Treatment	Exposure period
Autumn 1947	Not inoculated	Eleven months, starting at end of leaf-fall period in 1947.
Autumn 1948	Not inoculated	Twenty-three months, starting at end of leaf-fall period in 1948.
Autumn 1949	Inoculated	Eighteen months, starting May 4, 1950.

TABLE 2.—WEIGHT OF LEAVES EXPOSED PER UNIT SURFACE AND PERCENTAGE LOSSES (D.W. BASIS)

Year collected	Beech		Birch		Maple		Poplar	
	Gm.	Loss	Gm.	Loss	Gm.	Loss	Gm.	Loss
		%		%		%		%
1947	268	18.2	502	38.2	298	42.7	241	24.5
1948	218	41.4	241	51.9	325	55.8	213	49.8
1949	213	41.8	108	—	336	49.7	104	—

TABLE 3.—VOLUMES OF LEACHATES (IN LITRES) COLLECTED FROM 1948 LEAVES IN 1949 AND 1950 DURING THE INTERVALS INDICATED

Collection interval	Beech	Birch	Maple	Poplar
November-December, 1948	63.3	67.4	67.7	70.2
April, 1949	35.7	38.2	38.7	39.0
May, 1949	17.6	21.4	21.8	21.5
June, 1949	63.1	71.9	69.6	70.0
July, 1949	17.4	18.1	18.4	18.7
August-September, 1949	78.8	85.6	88.2	78.3
May-June, 1950	49.6	51.6	46.7	49.1
July, 1950	80.3	90.6	81.5	86.6
August-September, 1950	86.9	97.2	97.0	98.5
Total volumes collected	492.7	542.0	529.6	531.9

collection sites for each species of leaves. These were mixed with about a gallon of water and allowed to stand for several hours. The supernatant suspension then was filtered through cheesecloth into a watering-can and sprinkled over the leaves. Inoculations were made monthly from May to October, inclusive, in 1950 and in July, August and September in 1951.

The weights of leaves (oven-dry basis) exposed per square foot of tray surface and the percentages of loss in weight occurring during the exposure periods (Table 1) are presented in Table 2.

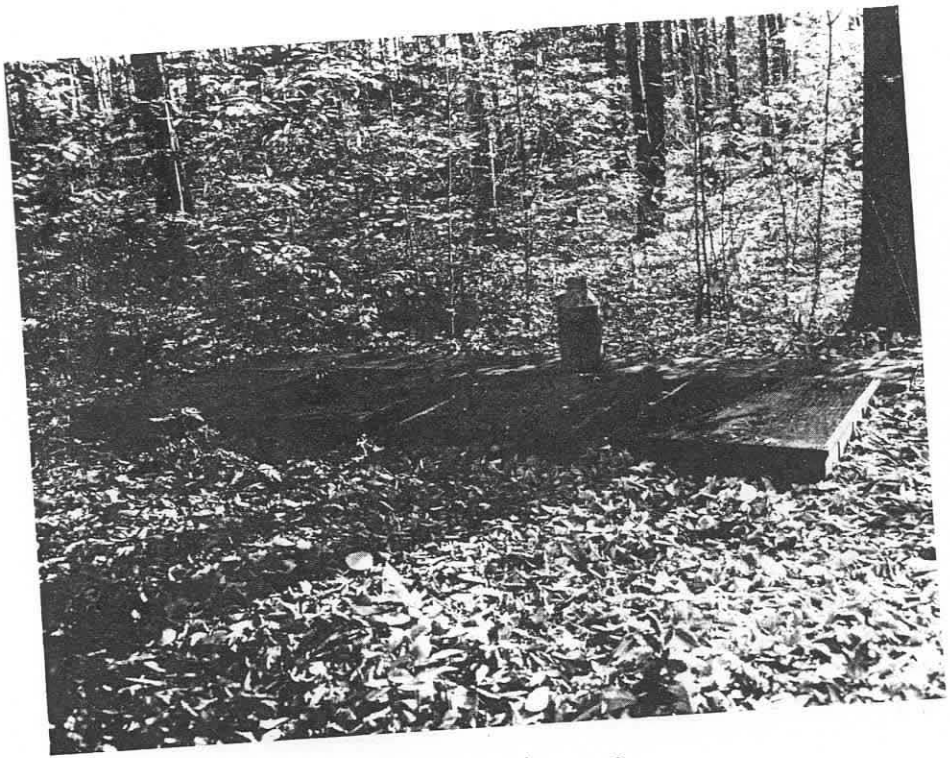


FIGURE 1. Leaf exposure

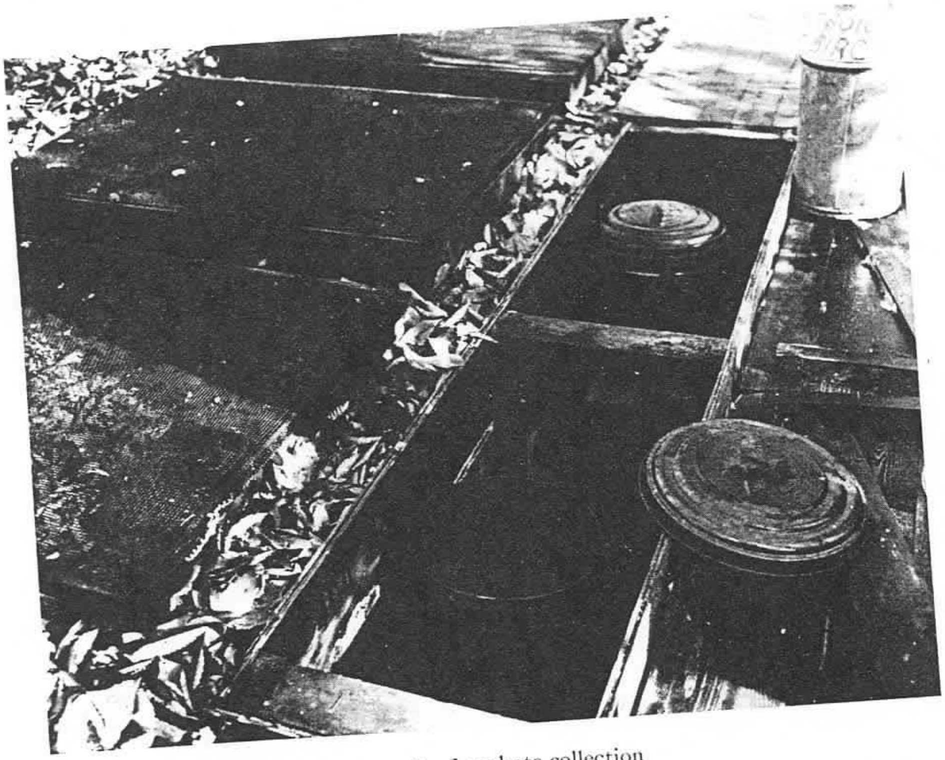


FIGURE 2. Leachate collection

The volumes of leachates gathered from the 1948 leaves during the leachate collection periods indicated are presented in Table 3. From these data and from the information given in the figures presented below, the total amounts of titratable acidity, total solids, ash, and ash alkalinity present in the leachates may be calculated.

With the exception of the winter months, leachates were collected after each rainfall of sufficient magnitude to cause percolation, filtered to remove suspended material, and the volumes obtained recorded. Routine determinations of the following characteristics were made on aliquots taken from each leachate collected:

1. pH, using a Beckman Model G potentiometer with glass-calomel electrodes;
2. Titratable acidity or alkalinity by titration with 0.01 N NaOH or HCl solution to pH 7;
3. Total solids and ash by the methods used for potable water (4); and
4. Ash alkalinity by the method of Purves (5).

Total nitrogen by the micro-Kjeldahl method (4) was determined on leachates collected in 1948 from leaves gathered in 1947, also on concentrates of leachates gathered on June 9, 1948. These concentrates were obtained by distillation and the degrees of concentration obtained were 55-, 25-, 50- and 50-fold, respectively for leachates from beech, birch, maple and poplar leaves of the 1947 collection. Free amino-nitrogen also was determined on these concentrates using the micro Van Slyke apparatus. In addition, the concentrates were centrifuged to remove suspended solids and aliquots of the supernatant solutions hydrolyzed for identification of the amino acids present. For hydrolysis an equal volume of concentrated HCl solution was added and the mixture refluxed for 24 hours in an all-glass apparatus. The HCl was removed from the hydrolysates by four evaporations to dryness under vacuum, a small amount of distilled water being added after each evaporation. The acid-free residues so obtained were analysed for amino acid content by paper partition chromatography (ascending technique). Identification of the amino acids was by means of R_f values and by comparison with standard solutions of amino acids of known identity.

Numerous collections of leachates were made, and since these were produced as a result of natural rainfall, these collections came at very irregular intervals. For convenience of presentation, therefore, the analytical data obtained have been calculated to a monthly or a bi-monthly basis. The pH values for leachates gathered during these periods have been averaged and the other data calculated as the mean values per unit volume of 10 litres. The information so obtained is presented in the form of curves suggestive of general trends in leachate characteristics with the progress of the season and of leaf decomposition. Detailed data will be presented for the 1948 leaves only. Deviations in characteristics shown by leachates collected from 1947 and from 1949 leaves, as compared with those of leachates obtained from 1948 leaves, will receive comment in instances in which such deviations seem to be large enough to have significance, even though the cause of the deviations be obscure.

EXPERIMENTAL RESULTS AND DISCUSSION

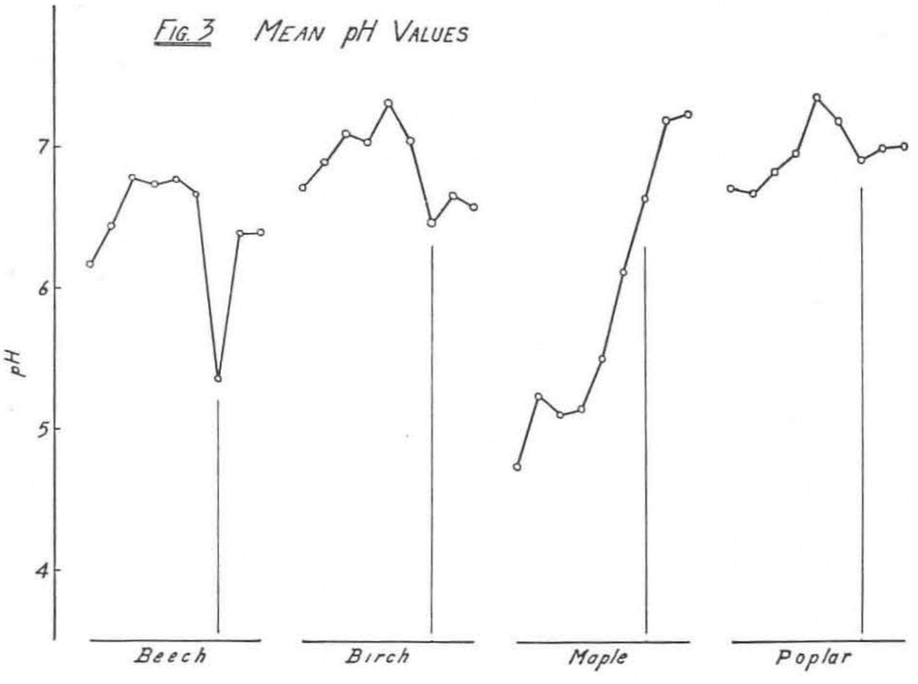
The pH trends for leachates from the four species of leaves (1948 collection) exposed during 1949 and 1950 are shown in Figure 3. In this and the subsequent figures the perpendicular lines beneath the curves indicate the values for leachates of the first collection interval of the second season of exposure. All values at the left of these lines are for leachate collections of the first season of exposure. The collection periods represented by the points plotted in Figures 3 to 6, inclusive, were as follows, reading from left to right in these figures; November-December, April, May, June, July, August-September, May-June, July and August-September. The analytical data for 1947 and for 1949 leaves, with which those given in Figures 3-6 are compared, were summarized in collection periods thus: for 1947 leaves, October-November, April, May, June, July and August-September, for 1949 leaves, May-June, July and August-September.

Examination of Figure 3 shows that, in each season of exposure, there is a general trend toward decreasing intensity of acidity of the leachates with advance of the season, this trend being much more marked in the first than in the second season. The great change occurring in successive collections of maple leachates is noteworthy.

The observation that the pH of leachates from decomposing leaves rises as decomposition progresses is in agreement with the earlier results of Stepanov (6, 7). It may be noted also that Marten and Pohlman (3) found that the pH values of decomposing leaves rose with advancing decomposition.

Secondly, it may be observed that, for the first season of exposure, the leachates from the different species of leaves may be arranged in order of

Fig. 3 Mean pH Values



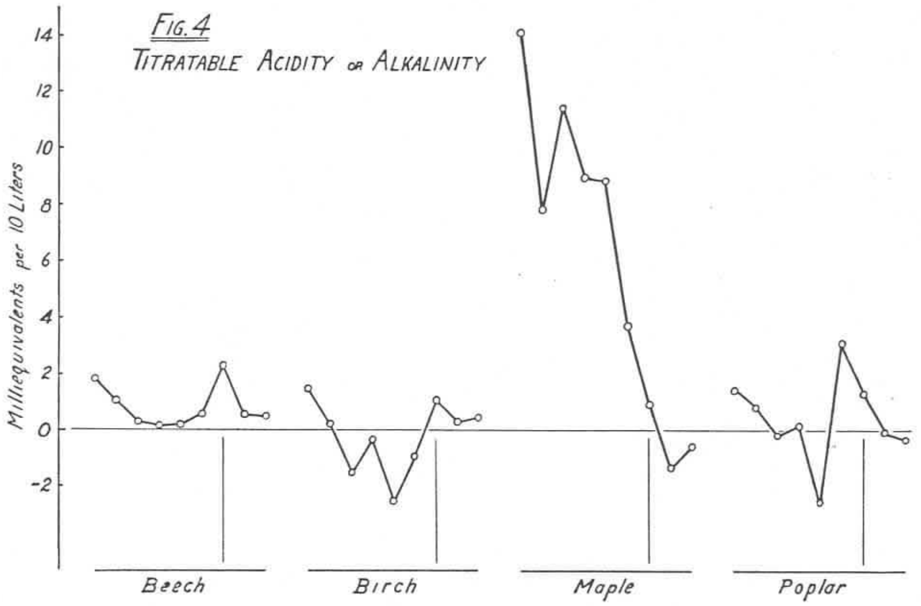


FIG. 4
TITRATABLE ACIDITY OR ALKALINITY

decreasing intensity of acidity, or pH, as follows: maple, beech, birch and poplar. Leachates from the latter two species are approximately equal in this respect. Those from poplar were the more acidic in the early part of this season and were slightly more alkaline for the last two collection intervals.

Leachates from 1947 leaves, exposed from autumn 1947 to autumn 1948, fell into nearly the same order of intensity of acidity, namely, maple, beech, polar and birch, the four curves being distinctly different throughout the season of 1948. For 1949 leaves exposed from May to September (inclusive) 1950 the order was maple, birch, beech, poplar. No definite explanation of the changing order of species can be given. It is thought possible, however, that the differences in weight of leaves exposed per unit area of tray surface may have constituted an important factor in this connection, and that, for example, the large weight of 1947 birch leaves, as compared to that of 1949 leaves of this species exposed, may account for the greater alkalinity of leachates from the former.

It may be noted that variations in mass of decomposing leaves per unit surface area is a natural condition in the forest floor, especially when the vegetation is deciduous and the floor has marked degree of micro-relief.

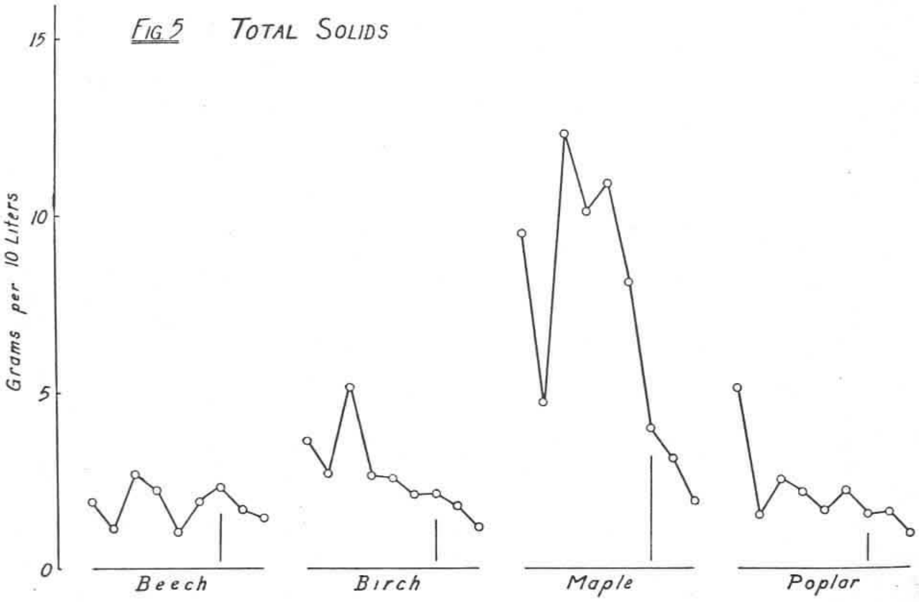
During the second season of exposure the order of decreasing intensity of acidity was the same for both 1948 and 1949 leaves and different from that for the first season. It was beech greater than birch and poplar approximately equal to maple, the slowly decomposing beech leaves giving the most intensely acidic leachates in the second season of exposure. Differences in intensity of acidity in the second season were small as compared to those during the first season, as Figure 3 demonstrates.

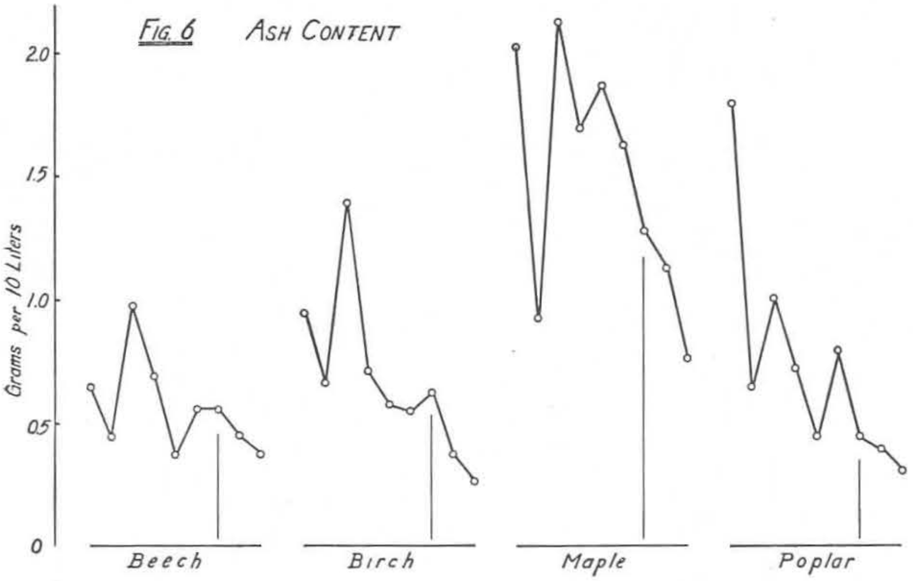
In Figure 4 the changes in the titratable acidities of the leachates from 1948 leaves are shown. Inspection of this figure shows that, during the first season of exposure, maple leachates possessed by far the greatest initial titratable acidity and exhibited the greatest over-all range in this characteristic. Beech leachates were next to those of maple in titratable acidity during this first season. In the initial season of exposure leachates obtained from 1947 and from 1949 leaves were similar in these respects. In the case of the 1947 leaves, however, birch leachates once more were different from those obtained from 1948 and 1949 leaves of this species in that they exhibited a much greater range of titratable acidity.

In the second season of exposure differences in the titratable acidities of leachates from different species were relatively small, and the acidities after the first collection period either were low or negative. In the second and third collection periods of this season, maple leachates tended to have the lowest acidities. This was true for both 1948 and 1949 leaves.

Of the four species studied, leachates from beech were the only ones which never gave a measurable amount of titratable alkalinity in either season of exposure. For both 1948 and 1949 leaves leachates from birch and poplar were found to possess titratable alkalinity (expressed as negative acidity in Figure 4) in the first season. The same was true for birch, but not for poplar leachates of the first season from 1947 leaves. In no case did maple leachates have titratable alkalinity in the first season of exposure. The sharp rise in the titratable acidity of poplar leachates at the end of the first season (Figure 4) was not shown in the case of the 1947 and 1949 poplar leaves.

The changes in the total solids contents of leachates from 1948 leaves are portrayed in Figure 5. These data show that first season maple leachates have by far the greatest total solids content per unit of volume, while first season beech leachates have the least. These remarks hold true also for leachates from 1949 leaves in the initial season of exposure. With 1947 leaves, however, the total solids content of leachates from birch leaves





was greater than that of leachates from maple. This is thought to be a consequence of the relatively large weight of birch leaves per unit area of the tray exposed in the 1947-48 season.

In the second season of exposure the total solids contents of leachates from different leaf species were small and closely similar. Nevertheless, the solids contents of maple leachates still were higher than those for leachates from the other species.

Figure 6 presents the data obtained for the ash contents of the leachates from the 1948 leaves. In respect of this component, as well as of titratable acidity and total solids, leachates from maple and from beech leaves are seen from Figure 6 to represent the extremes, maple leachates having high and beech leachates low ash contents with birch and poplar intermediate. Comparison with the data for 1947 and 1949 leaves in the first season of exposure indicated that this order held for the 1949 leaves. In leachates from 1947 leaves, however, the order of decreasing ash content was birch, poplar, maple, beech. Possibly the large quantity of birch leaves exposed per unit of surface was once again responsible for the position of birch leachates in the series just given. On the other hand, the order of weights exposed per unit of surface is not that of the ash content of the leachates when all four species are considered. The differing behaviour of the leachates for 1947 leaves in respect of ash content remains unexplained. Possibly seasonal climatic conditions are important in this connection.

In general, the ash contents of the leachates run more or less parallel to their total solids contents. This relationship is most clearly shown by leachates obtained in the second season of exposure, maple leachates standing highest in both these respects, those from the other three species being closely similar and less than for maple for both 1948 and 1949 leaves.

The values obtained for the alkalinity of the ash of leachates obtained from 1948 leaves are given in Figure 7. Once more the familiar pattern of maple leachates high, beech leachates low, appears. This pattern holds

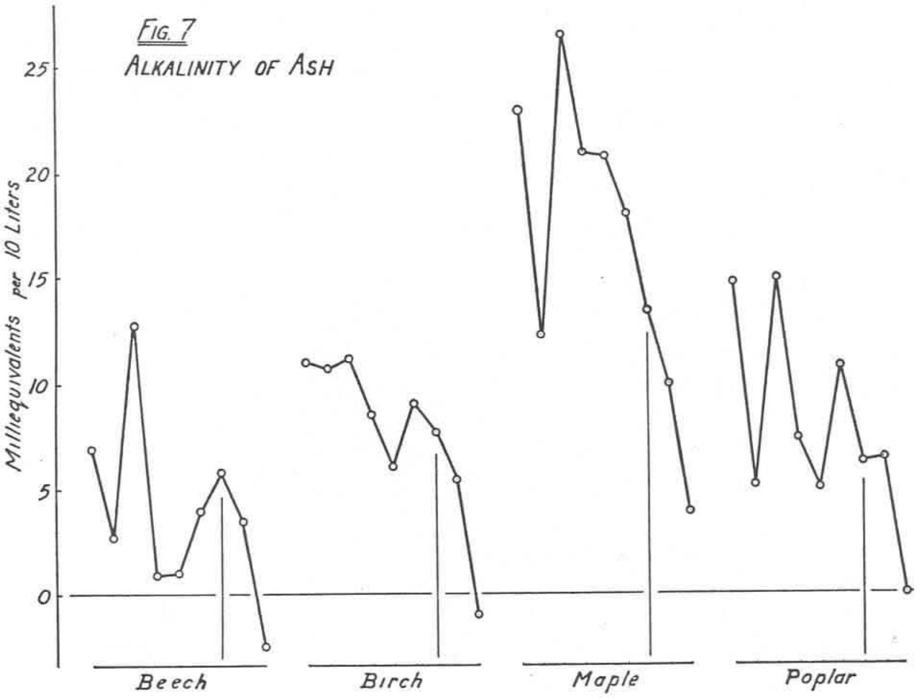


FIG. 7
ALKALINITY OF ASH

true also for both 1948 and 1949 leaves in both seasons of exposure. Leachates from 1947 leaves did not conform, birch leachates once more being out of the expected order and showing alkalinity greater than that of maple leachates. It may be noted also that the very sharp decline in ash alkalinity exhibited by all leachates from 1948 leaves in the second season of exposure was not shown by second season leachates from inoculated 1949 leaves.

In the opinion of the authors the most significant features of the data presented in Figures 3-7, from the standpoint of their relation to the podsolization process, are the relatively low pH values and the relatively high titratable acidities of the initial leachates obtained from the leaves. It seems noteworthy that, under field conditions, these initial leachates are produced in late autumn and early spring during periods of very low biological activity. Examination of Figures 3 and 4 shows that the pH values of the leachates increase and their titratable acidities decrease as conditions for microbial activity improve, and that these trends are reversed in late autumn and early spring. Further, these initial leachates, solutions of relatively high potential leaching capacity, are produced at periods when the moisture supply generally is abundant and the evaporation rate low, i.e., periods favourable for leaching.

In the opinion of the authors, however, too great emphasis should not be placed on the acidic characteristics of leaf leachates. Experimental work in progress indicates that acidity is not the only factor concerned in the movement of iron and aluminium by leachates from decomposing leaves, and that other characteristics may be equally or more important. It is recognized, moreover, that the biological conditions of the forest floor are not being reproduced completely under the experimental conditions discussed. This, it is believed, is particularly true of the faunal effect in leaf decomposition. The influence of the fauna of the forest floor on the characteristics of the leachates produced would, however, be expected to be at a minimum during late fall and early spring.

The significance of the differences exhibited by leachates from different species of leaves is not yet apparent. A factor complicating interpretation is the fact that the maple leaves used were produced by trees growing on a neutral to slightly alkaline soil formed from calcareous till, those of the other three species from acidic soil sites. The extent to which this difference in site conditions may be responsible for the differences in characteristics shown by leachates from maple leaves as compared to those from beech, birch and poplar leaves is unknown. Preparations are being made, however, for a comparison of maple leachates produced from leaves grown on the Grenville soil and from leaves grown on an acidic soil. It is hoped that the results obtained may assist in the interpretation of the data here presented.

The leachates obtained under the experimental conditions employed characteristically contained but small amounts of nitrogen. The data obtained from leachates collected during the summer of 1949 from leaves gathered in 1947 are presented in Figure ~~7~~8, in terms of milligrams of total nitrogen found per 10 litres of leachate. The collection intervals represented in this figure are the months of April, May, June, July, and August-September indicated by A, M, J, Jy, and A-S, respectively. Inspection of this figure shows that the highest concentrations of nitrogen generally were attained in June or July, and that in all collection intervals, with the exception of the July period, the nitrogen concentration in birch leachates was greater than in those from the other species of leaves. The total amounts of nitrogen recovered in the whole collection period, April to August-September, inclusive, were, for beech, birch, maple and poplar, 0.45, 1.44, 0.98 and 0.51 grams, respectively. The nitrogen contents of the organic material contained in these leachates, that is, material not volatile on the steam bath but volatile on ignition, were found to be higher for beech and poplar than for birch and maple leachates. The mean values for percentage of nitrogen in the organic material in the leachates obtained during the 1948 season were 1.72, 0.90, 0.74 and 1.31 for beech, birch, maple and poplar leachates, respectively.

Leachates of the June 9, 1948 collection were concentrated by vacuum distillation and the total nitrogen and apparent amino-nitrogen contents of these concentrates were determined, the latter by the Van Slyke micromanometric method. The results obtained are presented in Table 4. In

TABLE 4.—TOTAL NITROGEN AND AMINO-NITROGEN CONTENTS OF LEACHATE CONCENTRATES

Species	Total nitrogen	Amino-nitrogen	
	Mgm./l.	Mgm./l.	Per cent of total nitrogen
Beech	0.82	0.40	49
Birch	11.5	1.73	15
Maple	1.56	0.92	59
Poplar	0.56	0.32	57

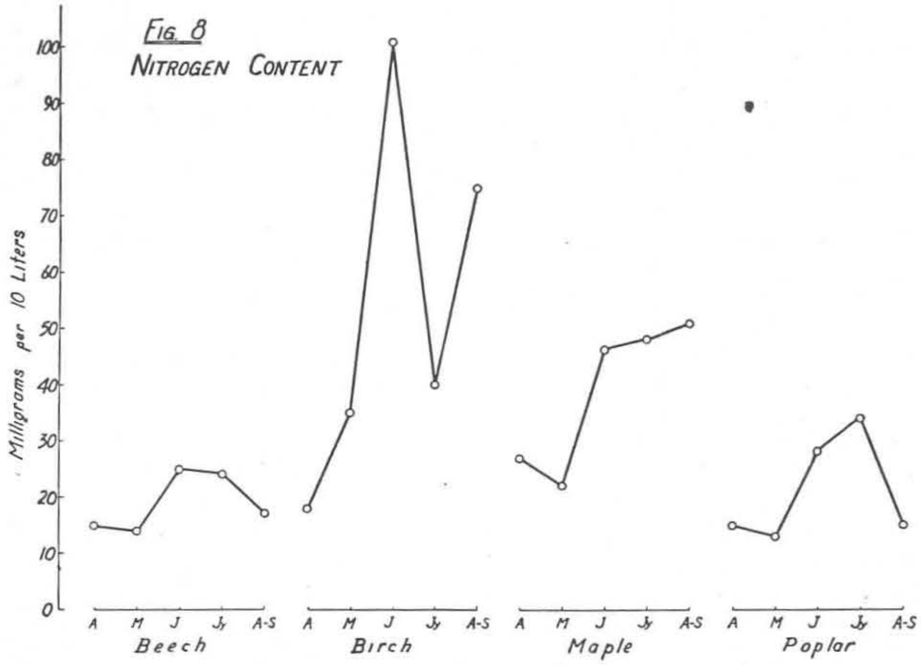


FIG. 8
NITROGEN CONTENT

this table the concentrations of total and of amino-nitrogen are given in terms of milligrams per litre of leachate.

Since it is well known that substances other than amino acids can yield free nitrogen under the conditions of the Van Slyke determination, the leachate concentrates were examined for the presence of amino acids using the paper partition chromatographic technique. The concentrates were centrifuged to remove suspended solid material before hydrolysis for estimation of amino acids. Identification of amino acids in the hydrolysates was by comparison with standard solutions of known amino acids and with R_f values recorded in the literature. In this manner tentative identification of the following amino acids was obtained, namely, (1) alanine, (2) aspartic acid, (3) glycine, (4) leucine (or isoleucine), (5) proline, and (6) valine (or norvaline). The distributions of these amino acids in the leachates from the four species of leaves were as follows: beech, 1, 2, 3, 6; birch, 1, 2, 3, 4, 6; maple, 1, 3, 6; poplar, 1, 3, 4, 5, 6. It is perhaps noteworthy that definite indications of the presence of alanine, glycine and valine (or norvaline) were obtained from leachates of all species of leaves examined.

SUMMARY

Chemical characteristics of leachates obtained by exposure of leaves of four species of deciduous forest trees (beech, gray birch, sugar maple and poplar) on trays placed in the soil of the forest floor have been investigated. It has been found (*a*), that such leachates tend to become less acidic as the time of exposure lengthens, but that this trend may be reversed during the interval between two growing seasons; (*b*) that the pH values and the titratable acidities of leachates from sugar maple leaves collected from a calcareous till soil approximately neutral in reaction are considerably lower and much greater respectively, than are the corresponding values for leachates from beech, birch and poplar leaves collected from acidic soil sites; (*c*) that the total solids and ash contents of leachates from the maple leaves also are greater than those of leachates from leaves of the other species; and (*d*) that the alkalinity of the ash of maple leachates also tends to be greater than that of leachates from the other species.

Observations on the nitrogenous fraction of the leachates have indicated that the total nitrogen content, always low, tended to be highest in June and July collections and that amino acids were present. Alanine, glycine and valine (or norvaline) were tentatively identified as present in leachate collections made in early June from all four species of leaves.

ACKNOWLEDGMENT

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